INTRODUCTION

Prior to 1981, browntail moth, Euproctis chrysorrhoea (L.), infestations were confined to two localized areas on Cape Cod National Seashore. However, in 1982, the infestation moved out of these areas to other areas, infesting more than 1,000 acres on the Park. Although there was a reduction in the browntail moth infestation in 1984, there were still areas that support moderate to high infestations. At the request of the Park Service, a biological evaluation of the insect was made by Forest Pest Management, Forest Service, USDA on Cape Cod National Seashore in May and June of 1985.

Objective

The purpose of the biological evaluation was to determine the expected degree of defoliation in those areas near or adjacent to private land or in high use recreational areas, and to determine actual damage caused by the insect.

SURVEY METHODS

Survey Area

Five areas supporting 60 percent ground cover of beach plum (Prunus maritima) and other primary host plants were evaluated for browntail moth. These areas were Herring Cove Beach, Race Point, Pilgrim Heights, and Highland Light (see maps).

Plots

Three sample plots each were established in Herring Cove, Race Point and Highland Light, and six plots in Pilgrim Heights. Each sample plot had a radius of 6 meters (19.2 feet). Host plants inside the radius were counted for an estimate of the average number of plums and other shrubs per plot. Portions of plants inside the radius were also included as part of the sample. The plot center of each plot was staked and flagged for future reference.

Within the sample plot, web density was determined by counting the number of webs on all the shrubs. If any portion of a shrub was inside the 6 meters, all webs on it were counted. The M^2 surface area of foliage of each plant within the plot was calculated from the diameter of each shrub (average length and width). The formula that was used to estimate surface area was half of the surface of a sphere, $S = \Pi d^2/2$ because the shrubs were roughly hemispherical in shape. Web density was also determined on some plums and other shrubs outside the plot for additional information on defoliation and damage.

If there were trees in these plots, they were not considered in the evaluation because larval feeding and other larval habits are different from those on shrubs.

Five webs were removed from beach plums and other primary host plants outside the plots in each area to determine the mean number

of larvae per web. The larvae were killed by boiling the webs in water for one-half hour at the Province Lands Area Park Headquarters in Provincetown. Then they were brought back to the Durham field office laboratory to extract the larvae from the silk-lined webbed chambers. Larvae from both single and consolidated webs were included in the total count.

Expected degree of defoliation was determined as follows: the amount of foliage consumed by a browntail moth larva x mean number of larvae per web times x number of webs per plot % by the amount of foliage in a plot in M^2. Estimated amount of shrub surface consumed by a browntail moth larva is about 170 cm^2 (0.017 $M^2 \pm .0025$)(Snowden 1984 unpublished data).

To test another means of predicting damage, after the foliage had leafed out on all plants in the plots, larval counts were made and recorded from 45 cm terminal and subterminal twig samples to correlate larval density and percent defoliation . These twig samples were selected at random within and near the plots. Percent defoliation caused by one or more larvae on 45 cm twigs was also recorded. Damage was also recorded in the plots. Additional data and observations were recorded from plants outside the plots as well.

RESULTS AND DISCUSSION

Percent of mortality from fifteen plots recorded on May 14 and June 19,1985 were as follows:

Area	Plot #	Number Plums, Other Shrubs 1)	Estimated Plant Mortality 1984	Total M^2 surface area of shrubs per plot 5/14/85	Total M^2 surface area of shrubs per plot 6/19/85	Percent Mortality 1985
Herring Cove	1 2)	20	25	122	9	93
Beach	2 2)	22	--	79	9	89
	3	7	--	40	5	88
Race Point	4 2)	27	20	116	10	92
	5	17	--	61	0	100
	6 2)	13	45	29	7	75
Pilgrim	7	15	--	37	2	95
Heights	8	8	--	17	0	100
	9	6	--	35	0	100
	10	6	--	23	1	97
	11	14	--	35	0	100
	12	9	--	45	0	100
Highland	13 2)	4	55	65	0	100
Light	14	4	--	28	10	65
	15 2)	10	50	9	0.2	100
Mean		12		49.4 ± 8(S.E.)	3.5 ± 1 (S.E.)	93

1) Rounded off to the nearest plant.
2) Sample plots used in 1984.

The data indicate that two to three consecutive years of severe defoliation by the larvae will kill most plums and other preferred host plants.

Out of the 182 plants examined in 15 plots, 101 (55%) were infested with webs. Comparing web density to expected percent defoliation was as follows:

Location	Plots #	Number Plants 1)	Total M^2 surface area of shrubs	Number webs/ Plot	Number Larvae Web X Amt. Foliage Consumed by a Larvae	Expected Defoliation 2)
Herring Cove	1	20	122	24	1.8	35(M)
Beach	2	22	79	13	1.8	29(M)
	3	7	40	10	1.8	45(M)
Race Point	4	27	116	39	1.8	60(M)
	5	17	61	69	1.8	100(S)
	6	13	29	14	1.8	38(M)
Pilgrim	7	15	37	9	1.8	43(M)
Heights	8	8	17	23	1.8	100(S)
	9	6	35	34	1.8	100(S)
	10	6	23	10	1.8	78(S)
	11	14	35	65	1.8	100(S)
	12	9	45	10	1.8	40(M)
Highland	13	4	65	109	1.8	100(S)
Light	14	4	28	49	1.8	100(S)
	15	10	9	50	1.8	100(S)
Mean		12	49	35		

1) Rounded off to the nearest plant.

2) L = light (0-25%); M = moderate (26-50%); H = heavy (51-75%); S = severe (76-100%).

Total number larvae/web in 25 webs was 141±25.7. Since 15% of the larvae are usually killed by parasites and 20 percent by winter mortality, adjusted number larvae per web was 106. Out of the 25 webs, only 1 was a consolidated one. The rest of the webs were single ones. Number larvae/web ranged from 24 to 686. Analysis of variance for unequal sample size showed no significant difference in the mean number larvae/web collected from four areas. Computed $F = 1.94$; $F = .95\ (3.21) = 3.07$.

Percent expected defoliation could not be compared to percent actual defoliation because about 93 percent of the beach plums and other host plants were dead in most plots. However, of the remaining live foliage, the total M^2 surface area of shrubs and percent defoliation were as follows:

Area	Plot #	Plants 1)	Total M^2 Shrub/ Surface 6/19/85	Number live Webs 6/19/85	Number Webs/ Plant	Percent Actual Defoliation
Herring	1	20	9	14	0.70	80
Cove Beach	2	22	9	7	0.32	73
	3	7	5	0	0	28
Race Point	4	27	10	17	0.62	80
	5	17	0	9 2)	0.52	-
	6	13	7	7	0.53	15
Pilgrim	7	15	2	6	0.40	70
Heights	8	8	0	0	-	-
	9	6	0	0	-	-
	10	6	1	5	0.83	95
	11	14	0	0	-	-
	12	9	0	6 2)	0.66	-
Highland	13	4	0	57 2)	0.66	-
Light	14	4	10	31	7.75	80
	15	10	0.2	21	2.10	100
Mean			5.4	9.6	0.68±0.2(S.E.)	68± 11.0(S.E.)

1) Rounded off to the nearest plant.
2) Data not analyzed.

Spearman rank correlation coefficient indicated a high positive correlation at 5 percent level between number webs/plant and percent actual defoliation, $r_s = .83$ or $r^2 = 68\%$. This means that 68 percent of the variation in percent actual defoliation was accounted by the webs on the plants in the plots. The variable 7.75 in plot 14 was dropped because it was an erratic observation. If mean total M^2 surface area of shrubs is 5.4, the average plot should have been 100 percent defoliated because the larvae should be capable of consuming 17 M^2 surface area of shrubs ($106 \times 9.6 \times .017 = 17.2\ M^2$). The plots were not completely defoliated probably because little foliage was available for the larvae and they moved out of these plots to areas with foliage. When feeding population approaches the point of severe defoliation, larvae will wander and congregate on any available food, usually on the edge of the defoliated area. Defoliation, thereafter, proceeds in a discrete feeding front. The density of late stage caterpillars is inversely proportional to the degree of defoliation since larvae are constantly moving out of its defoliated areas (Schaefer, 1974). Although there was not sufficient foliage to compare with

confidence the percent of actual defoliation to number webs/plant, it is evident that one web/plant will cause heavy defoliation (51-75%). This was substantiated from data collected in 1984.

Correlating larval counts on 45 cm terminal and subterminal twigs to percent defoliation in each plot were as follows:

Area	Plot #	Number of 45 cm twigs	Mean larvae/ 45 cm twig	Mean Percent defol	Percent Defoliation/ larvae
Herring Cove	1	25	4.5	40	8.89
Beach	2	23	2.2	21	9.54
	3	26	2.1 1)	14	6.67
Race Point	4	20	1.0 1)	2	2.00
	5	20	1.9 1)	4	2.10
	6	24	1.6	6	3.75
Pilgrim Heights	7	21	1.7 1)	5	2.94
	8	20	2.6 1)	15	5.77
	9	-			
	10	20	6.9 1)	25	3.62
	12	20	1.2	2	1.67
Highland Light	13	20	7.9 1)	44	5.57
	14	20	2.7 1)	37	13.70
	15	21	10.9 1)	41	3.96
Mean		280	3.6	20	5.4 ± 0.9(S.E.)

1) Does not include larvae in prewebs on some branches.

Spearman rank correlation coefficient indicated a high positive correlation at 5% level between mean number larvae/45 cm terminal to mean percent defoliation, $r_s = .95$ or $r^2 = 90\%$. This means that 90 percent of the variation is accounted for by the number larvae found on 45 cm. terminals. The data indicates that one larva caused about 5 percent defoliation in the plot. No data was recorded to indicate how much defoliation might have been caused by larvae in prewebs.

Additional data in determining number larvae/45 cm terminals to mean percent actual defoliation taken at random outside the plot areas were recorded as follows:

Number Larvae 45 cm terminal	Number of Observations	Mean Defoliation	Percent Defoliation/ Larvae
1	23 1)	13	13
2	18	19	10
3	12	28	9
4	12	43	11
5	5	52	10
6	7	55	9
7	-	-	-
8	8	53	7
Mean=4	85	39	9.8 ± 0.7(S.E.)

1) Three observations were excluded because defoliations were 80, 90, and 100 percent.

Spearman rank correlation coefficient indicated a higher positive correlation at 5 percent level between number larvae/45 cm terminals and mean percent defoliation outside the plots than inside the plots, $r_s = .96$ or $r^2 = 93\%$. Each larva caused about 10 percent defoliation. Why defoliation caused by each larvae outside the plots is greater than in the plots is not certain, but it may be because more foliage was available for the larvae.

Web mortality during the spring was high -- 63 percent in the plots. If viable webs were on any portion of a branch that was dead, larvae either died after emergence or migrated to live plants.

Plants with no webs were still susceptible to defoliation because larvae migrated to those plants when their supply of food became scarce. It was not unusual to see larvae migrating on the ground to other plants.

Prewebs made by the early spring larvae were common on many plants. When the larae were not feeding, they could be found inside these prewebs. The prewebs were flimsy and transparent, and were located on the lower branches and the crotches of branches that served as a resting niche or protection for larvae. Webs made by larvae in the fall are tough, silken hibernacula located at the ends of twigs in which the larvae overwinter.

Construction of prewebs is characterized only in the early instar larvae. Fourth and fifth instar larvae did not make prewebs, but fed or rested on the foliage or stem.

When larvae count on 45 cm twigs were made, some were in prewebs. Defoliation would likely be higher if branches had prewebs on them, but my data did not show it. The number of larvae on prewebs ranged from 24 to more than 150.

There are indications that plant mortality will be higher in 1986 because plants with about 50 percent mortality already will be killed next spring. Also, the infestation is expected to expand to newer areas because the population is still high.

Although Eastern tent caterpillars contributed to some of the defoliation in plots 1 and 2, browntail moth is the primary pest on beach plum and other preferred host species, and is responsible for the mortality.

Data analyzed in this evaluation is useful in assessing defoliation and damage by browntail moth, but more data is needed to relate web density to actual defoliation and damage.

CONCLUSION

It is unfortunate that the plot system was not tested sooner. Mortality of shrubs limited its value. However, the work does indicate that one web or more per shrub will result in heavy defoliation - a useful starting point for evaluation purposes. Using terminal twigs to predict defoliation is accurate, but evaluation must be done as soon as the larvae begin to feed. Thus the technique can be used for a prespray survey, but a biological evaluation must be done much earlier.

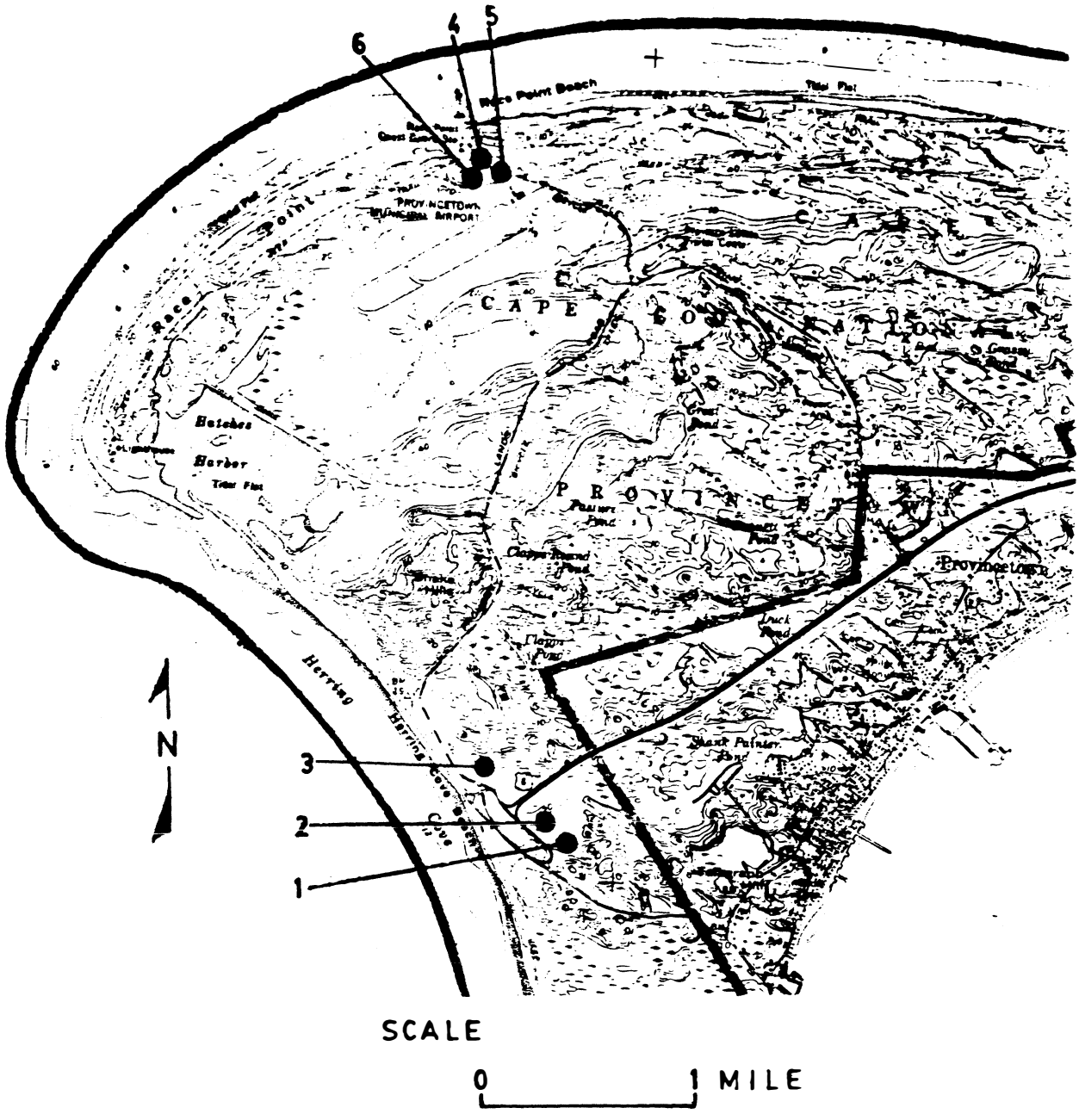
Since browntail moth is killing plums and other preferred host shrubs in old infested areas, the population is expected to move to new areas and continue the existing moderate to high infestation levels.

Although field evaluations of aerially applied Thuricide 16B and Dipel flowable conducted by APHIS were not successful in reducing the population in 1974, laboratory tests indicated that both formulations of Bt at dosages of 1-8 BIU were effective on larvae. In 1985 the National Park Service and the Provincetown Center for Coastal Studies conducted expermental field tests of Bt on browntail moth larvae on thirty 25 M^2 plots. The results of the tests are not yet available. However, if the results are promising, the Park Service should consider treating beach plums and other primary host plants in old infested areas to protect them from further defoliation and to prevent the infestation from expanding to new areas.

A biological evaluation should be made in the spring to assess expected defoliation and damage caused by the insect.

REFERENCE

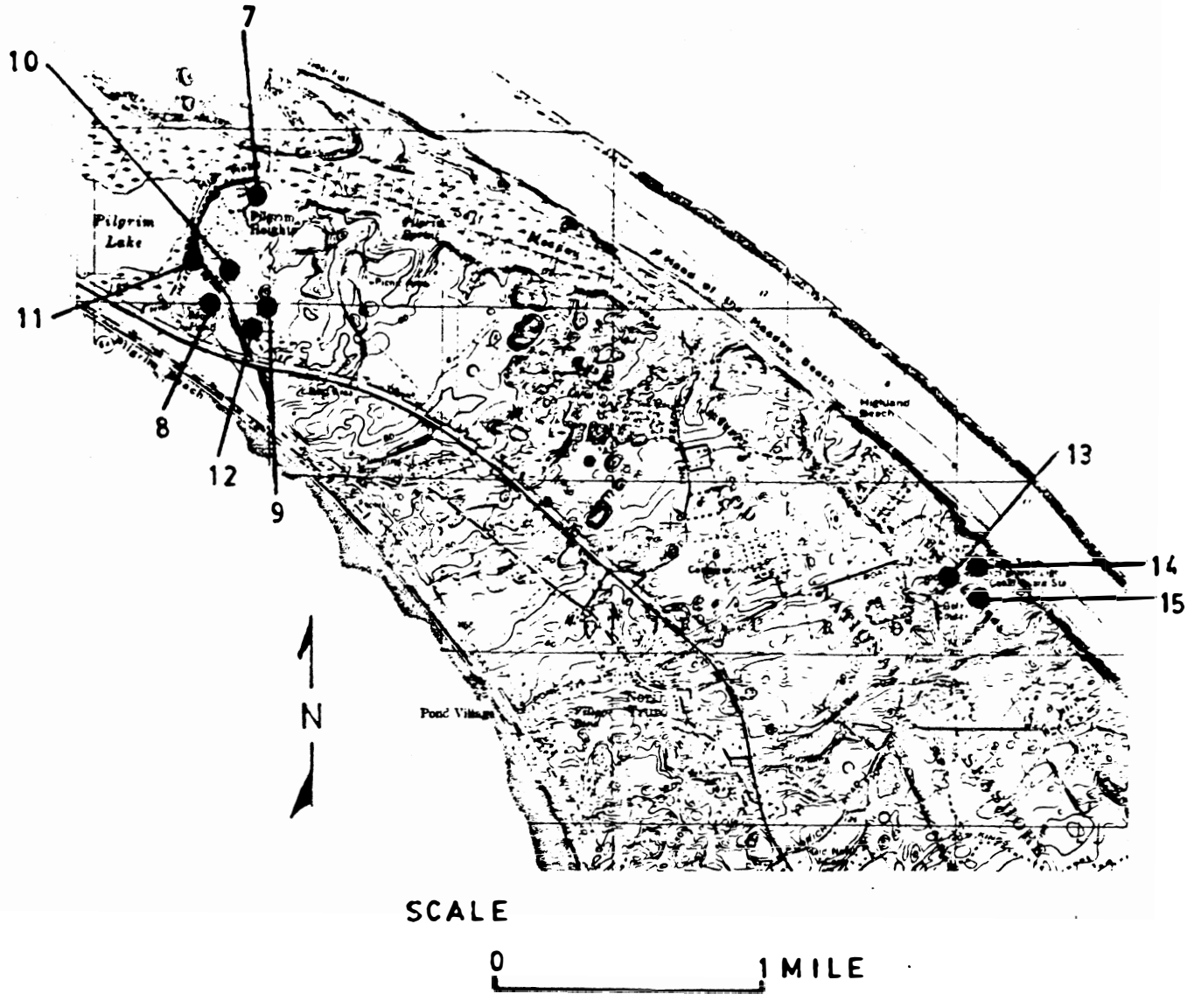
Schaefer, Paul W. 1974. Population ecology of the browntail moth (Euproctis chrysorrhoea L.) (Lepidoptera: Lymantriidae) in North America, Ph. D. Dissertation; Univ. Maine. pg. 80-84; 137-138A.



• Location of plots

MAP 1 1985 Browntail Moth Survey

Cape Cod National Seashore



● Location of plots

MAP 2 1985 Browntail Moth Survey

Cape Cod National Seashore